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(12) # EUROPEAN PATENT APPLICATION

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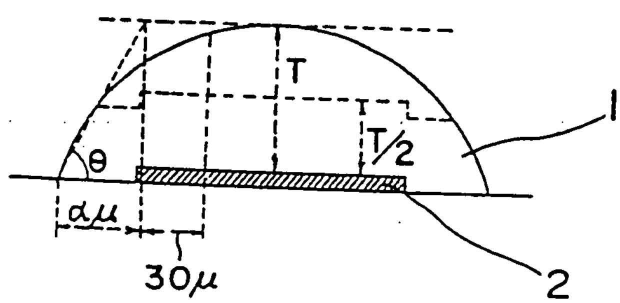
(54) ## LIQUID-CRYSTAL MULTI-COLOR DISPLAY DEVICE.

(57) In a liquid-crystal multi-color display device, if a color filter (2) is formed by printing over or under an electrode (1), the film thickness does not become uniform but forms steps, causing the orientation processing to become non-uniform and reducing the conductivity of the electrodes. With this invention, the color filter (2) is formed by printing in compliance with the following equation (I) in which the printing parameter has a value α of greater than 20, and duplication on the neighboring color filters ranges from $\alpha/3$ to $(\alpha + 30)\ \mu$, so that the surface is smoothed; T denotes a maximum film thickness of the color filter (2), and θ denotes an internal contact angle defined by a line that connect a point corresponding to a position of film thickness T/2 on the surface of color Filter (2) and an intersecting point of the edge of color filter (2) and the substrate relative to the substrate.



EP 0 186 710 A1

SPECIFICATION

Title of the Invention

Multicolor Liquid Crystal Display Device

Field of Technology Associated With the Invention

The present invention relates to a multicolor liquid crystal display device. More specifically, it relates to a multicolor liquid crystal display device wherein pixels comprised of a substrate having color filters laid above or beneath electrodes arranged on the substrate perform a multicolor display when applied with a signal corresponding to each pixel, the color filters being formed by the use of a printing process.

Background Art of the Invention and Technical Problem To be Solved by the Invention

Hitherto, in the multicolor liquid crystal display device, as a method for providing the color filters, it is well known to use a method comprising forming gelatin layers above or beneath the electrodes on an inner surface of the substrate and dyeing the gelatin layers to form the color filters. However, in the case of this method, there has been a problem in that both the water resistance and the heat resistance are low. In addition, in order to perform a multicolor patterning, a resist layer for anti-dyeing must

be formed for each color by the use of a photolithographic process and removed subsequently, with the consequence that it must employ an increased number of process steps, thereby increasing the price of the product.

In view of the above, the inventors of the present invention had got an idea of forming the color filters by the use of a printing process and had completed the following invention with a view to solving the above discussed problems, which was applied for patent in Japan (Japanese Patent Application No. 58-119281). Namely, this invention is a color filter for a liquid crystal display device characterized in that a print layer formed with the use of an ink containing, as its primary constituent, a polyamic acid mixed with a suitably selected coloring agent or the like is formed on a glass substrate. However, continued research subsequently performed has revealed that this method has the following problems. That is, it has been found that it has a problem or the like with respect to the uniformity and the dimensional precision of the thickness of a film printed for forming the color filter and, therefore, it is difficult to make the color filter comparable with or superior to that according to the conventional method in terms of the display quality. In other words, in the case with the printing process, and when it is viewed as a total color filter, an indentation between portions where the film thickness is great and small (hereinafter referred to as

"indentation") tends to be formed. In the case where the indentation is great, no orientation treatment called rubbing can be effected uniformly over the entire surface of the substrate, and therefore, the display quality is adversely affected. Moreover, in the liquid crystal device of a type wherein a transparent electroconductive film is provided over the color filter, the indentation constitutes a cause of failure in electroconductivity and shortage in electroconductivity. Even if the electroconductivity is secured, in order to form a highly precise pattern, problems tend to occur at the time of masking during the subsequent patterning of the transparent electroconductive layer. In order to remove these problems, it can be contemplated to provide an overcoating layer on the surface thereby to improve the smoothness of the indentation, but it is technically difficult and reduces the merits of the printing process which is low in cost.

Means for Solving the Problems

In view of the above, the inventors have found as a result of the further continued research that, when the color filter is formed by the use of the printing process, the shape thereof represents a semispheroidal or trapezoidal shape or the like, and have completed the present invention based on the finding. That is, the multicolor liquid crystal display device to which the present invention pertains is characterized in that the color filter to be

provided above or beneath the electrode is formed by the use of a printing process so that the printing parameter α expressed by the following equation is not smaller than 20 and the overlapping between the neighboring color filters is within the range of $\alpha/3 \sim (\alpha + 30)\mu$:

$$\alpha = \frac{T(\mu)}{\tan\theta} \qquad \ldots\ldots (1)$$

[wherein T represents the maximum film thickness of the color filter and θ represents the contact interior angle formed, relative to the substrate, by a straight line drawn so as to pass through both the position on a surface of the color filter where the film thickness represents T/2, and the point of intersection between an edge of the color filter and the substrate.]

Effects of the Invention

Since the present invention is constructed as hereinbefore described, the following effects can be obtained. That is, because of the printing process used, the color filter can be formed in a simplified manner and at a reduced cost. Important of all is that, since specific printing conditions are employed for the formation of the color filter, the surface can be smooth and, therefore, the display quality can be improved.

Embodiment

Hereinafter, the present invention will be described in detail in connection with an embodiment thereof with reference to the accompanying drawings.

The drawings altogether show one embodiment of a multicolor liquid crystal display device of the present invention, wherein Fig. 1 is an explanatory diagram, on an enlarged scale, showing one pixel, Fig. 2 is an explanatory diagram, on an enlarged scale, a plurality of pixels showing the adjoining conditions thereof, and Fig. 3 is a fragmentary sectional view.

In the drawings, 1 represents a color filter, 1R represents a red color filter, 1G represents a green color filter, and 1B represents a blue color filter. 2 represents electrodes, 3 represents orienting films, 4 represents a glass substrate, 5 represents a polarizing plate, 6 represents a back-light, and 7 represents a liquid crystal.

The reason that in the present invention, the printing parameter α is selected to be not smaller than 20 is as follows. If the value α is smaller than 20, the contact interior angle θ will become great resulting in the increased indentation. Where a method is employed to make the neighboring color filters overlap with each other in order to smooth the indentation, the range of tolerance will be extremely narrowed and the printing cannot be performed to a precision. Accordingly, even if such is theoretically possible, the fact is that the manufacture is impossible. By way of example, in the case where the value α is 10, in order to obtain a multicolor liquid crystal display device having a good display quality without any defect in

orientation, the overlapping of the neighboring color filters must be restricted within the range of 5 ∿ 10 μ. However, the presentday printing technology is still far from the achievement required to limit an error in overlapping to not greater than 5 μ.

The reason that the overlapping of the neighboring color filters is limited to not smaller than $\alpha/3$ μ is as follows. If it is smaller than that, a sufficient orientation treatment cannot be achieved because of the inferior smoothness and it will constitute a cause of leakage of back light (white color light) at non-pixel areas. When it is made not smaller than $\alpha/3$ μ, the indentation can be made not greater than 2/3 of the film thickness T and, moreover, since an acute portion of the angle in the vicinity of an edge of the color filter can be eliminated, the indentation can be smoothed with minimization of the defect in orientation. In addition, even in the case where the transparent electroconductive layer is formed over the color filter, a device in electroconductivity can be eliminated and the patterning can be made easy. Preferably, by making it not smaller than $\alpha/2$ μ, a defect in orientation attributable to the indentation can be eliminated.

On the other hand, the reason for the limitation to not greater than $(\alpha+30)$μ is as follows. Although it is necessary to increase the film thickness at the pixel area rather than the non-pixel area in order to avoid the defect

in orientation, an objective can be generally attained by restricting the overlapping of the neighboring color filters to the above mentioned range. If it may happen that the film thickness at the non-pixel area is greater than that at the pixel area, there will be no practical problem since, so far as falling within the above mentioned range, it is possible to limit to a very slight width. The reason therefor will now be described in detail. By selecting the value α to be not smaller than 20 as hereinbefore described, the necessity will arise to select a printing ink of relatively low viscosity and the shape of the ink after the printing will necessarily become smooth (see Fig. 1). Accordingly, even at a position spaced $(\alpha+30)\mu$ from an edge of the ink, it is at a position lower than the maximum film thickness T (μ), and it will represent a moderate portion having a small inclination. When a printed material is actually measured, the film thickness is found to be $0.8T \sim 0.9T$ (μ) on an average. More preferably, by making the overlapping portion not greater than $(\alpha+10)\mu$, the smoothing can be further promoted.

It is to be noted that, when the width of the electrode is selected to be a μ, the value α must be $20 \sim 2a$. A condition required for the smoothness to be maintained when α is 2a is such that the overlapping range is $2a/3 \sim (2a+30)\mu$. While there will be no problem in the case of $2a/3$ μ, in the case of $(2a+30)\mu$, the color filter

will intrude (a+15) at minimum into the neighboring pixel and the two color filters overlap, making it dark. Although there will be no problem in terms of visibility if the size of the pixel is large and that portion where the two color filters overlap with each other has a surface area equal to 10% of the total surface area of the pixel, it is still preferred that there is no intrusion into the neighboring pixel. In such case, the permissible range of overlapping is 2a/3 ∿ a μ, and it must be rendered a/3μ, thus narrowing the permissible range. Especially in the case of the highly precise display device, a is not greater than 50 μ and the permissible range is narrow, posing a problem during the manufacture by printing. Therefore, when α is not smaller than 2a, it will result in that the manufacture is in fact impossible.

In the present invention, the printing process is not always limited to a specific one. Any of a silk screen printing method, a letterpress printing method, a gravure printing method, a gravure offset printing method and other printing methods can be suitable adopted. Needless to say, consideration must be made to the viscosity of the ink appropriate to the respective printing method in order for the above mentioned requirements to be satisfied. By way of example, in the case of the silk screen printing method, 1,000 ∿ 50,000cps is preferred; in the case of the letterpress printing method, 50 ∿ 10,000cps is preferred; in the

case of the gravure printing method, 10 ∿ 5,000cps is preferred; and in the case of the gravure offset printing method, 10 ∿ 5,000cps is preferred.

The type of ink employed may be one containing, as its primary constituent, a component wherein a coloring agent is mixed with or dissolved in at least one resin selected from the group consisting of polyimide type resin, acrylic type resin, polyvinyl alcohol type resin, polyester type resin, epoxy type resin, polyurethane type resin, polysulfone type resin, melamine type resin and silicone type resin. If the polyamic acid is used as a binder, the heat resistance as well as the printing adaptability can be improved. As to the coloring agent, it may be suitably selected from any dyes and pigment. As a dye, an oil-soluble dye is preferred, and examples thereof include a KAYASET system (manufactured by Nippon Kayaku Co.), an OILCOLOR system (manufactured by Orient Kagaku Co.) and an OLEOSOL system (manufactured by Sumitomo Kagaku Co.). In the case of the pigment, the use of a pigment having a small particle size and an excellent transparency can be recommendable.

The multicolor liquid crystal display device to which the present invention pertains can be applicable not only where a standard matrix substrate utilizing a glass substrate or a film substrate is employed, but also where an active matrix substrate such as, for example, a silicon

substrate with switching transistor built therein, an SOS substrate or a glass substrate with thin-film transistor formed therein is employed.

As hereinbefore described, since the multicolor liquid crystal display device according to the present invention is constructed by the printing process, the color filter can be formed in a simplified manner and at a reduce cost, and most important of all is that, since the printing condition for the formation of the color filter is specified, the surface can be smoothed and, therefore, the display quality can be improved.

Scope of Claim

(1) A multicolor liquid crystal display device characterized in that a color filter to be formed above or beneath an electrode is formed by the use of a printing process so that the printing parameter α expressed by the following equation is not smaller than 20 and an overlapping between the neighboring color filters is within the range of $\alpha/3 \sim (\alpha + 30)\mu$:

$$\alpha = \frac{T(\mu)}{\tan\theta} \qquad \ldots\ldots (1)$$

[wherein T represents the maximum film thickness of the color filter and θ represents the contact interior angle formed, relative to a substrate, by a straight line drawn so as to pass through both the position on a surface of the color filter where the film thickness represents T/2, and the point of intersection between an edge of the color filter and the substrate.]

(2) The multicolor liquid crystal display device as defined in Claim 1, wherein, when the width between the electrodes is a μ, said α is $20 \sim 2a$.

(3) The multicolor liquid crystal display device as defined in Claim 1, wherein a printing ink is one containing, as its primary constituent, a component wherein a coloring agent is mixed with or dissolved in at least one resin selected from the group consisting of polyimide type

resin, acrylic type resin, polyvinyl alcohol type resin, polyester type resin, epoxy type resin, polyurethane type resin, polysulfone type resin, melamine type resin and silicone type resin.

(4) The multicolor liquid crystal display device as defined in Claim 1, wherein the printing process is a silk screen printing method and wherein the viscosity of an ink is 1,000 ∿ 50,000cps.

(5) The multicolor liquid crystal display device as defined in Claim 1, wherein the printing process is a letterpress printing method and wherein the viscosity of an ink is 50 ∿ 10,000cps.

(6) The multicolor liquid crystal display device as defined in Claim 1, wherein the printing process is a gravure printing method and wherein the viscosity of an ink is 10 ∿ 5,000cps.

(7) The multicolor liquid crystal display device as defined in Claim 1, wherein the printing process is a gravure offset printing method and wherein the viscosity of an ink is 10 ∿ 5,000cps.

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Fig. 1

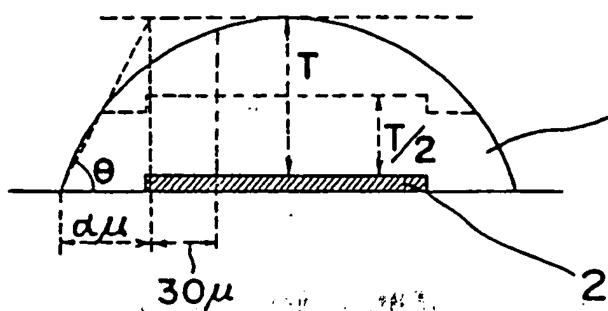


Fig. 2

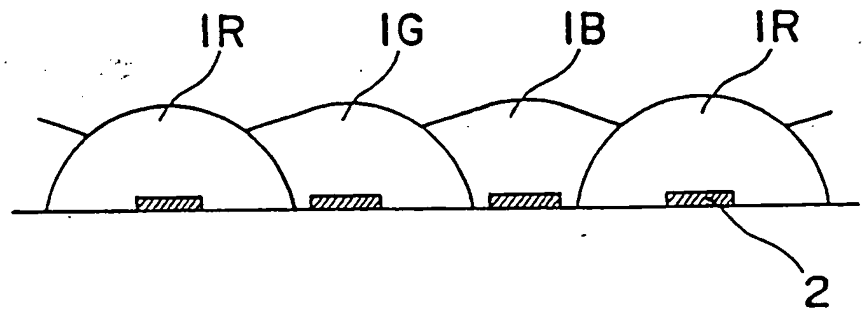
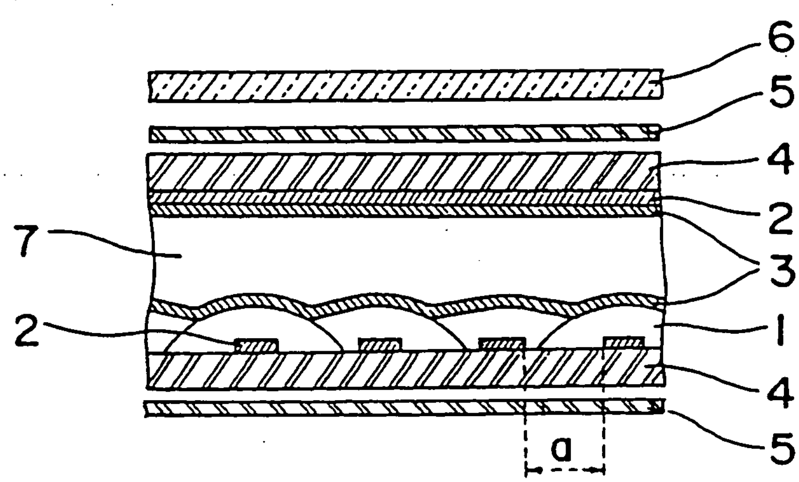


Fig. 3



Reference Numerals Used in the Drawings

1 ..... Color filter

1R ..... Red color filter

1G ..... Green color filter

1B ..... Blue color filter

2 ..... Electrode

3 ..... Orienting layer

4 ..... Glass substrate

5 ..... Polarizing plate

6 ..... Back light

7 ..... Liquid crystal

INTERNATIONAL SEARCH REPORT

International Application No. PCT/JP85/00333

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl[4] G02F1/133, G02B5/20, G09F9/35

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC	G02F1/133, G02B5/20, G09F9/35

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

Jitsuyo Shinan Koho	1966 - 1985
Kokai Jitsuyo Shinan Koho	1971 - 1985

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category*	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	JP, A, 58-46326 (Sharp Corp.) 17 March 1983 (17. 03. 83) Column 5, line 5 to column 7, line 9 & DE, A, 3234110 & GB, A, 2109123	1 - 7
A	JP, A, 58-46325 (Sharp Corp.) 17 March 1983 (17. 03. 83) Column 6, line 10 to column 9, line 1 & DE, A, 3234110 & GB, A, 2109123	1 - 7
A	JP, A, 58-50583 (Suwa Seikosha Kabushiki Kaisha) 25 March 1983 (25. 03. 83) Column 4, line 6 to column 4, line 9 (Family : none)	1 - 7
A	JP, A, 59-61818 (Suwa Seikosha Kabushiki Kaisha) 09 April 1984 (09. 04. 84) Fig. 1 & FR, A, 2534052 & GB, A, 2130781 & DE, A, 3313804	1 - 7

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
September 9, 1985 (09. 09. 85)	September 17, 1985 (17. 09. 85)
International Searching Authority [1]	**Signature of Authorized Officer [20]**
Japanese Patent Office	

International Application No. PCT/JP85/00533

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	JP, A, 59-29225 (Matsushita Electric Industrial Co., Ltd.) 16 February 1984 (16. 02. 84) (Family : none)	1 - 7
A	JP, A, 55-32026 (Suwa Seikosha Kabushiki Kaisha) 06 March 1980 (06. 03. 80) Column 4, line 5 to column 6, line 13 (Family : none)	1 - 7

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers............ because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers............ because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.